Beach Wizard: Development of an Operational Nowcast, Short-Term Forecast System for Nearshore Hydrodynamics and Bathymetric Evolution

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Award Number: N000140510266

LONG-TERM GOALS

The long-term goals are to provide accurate and detailed predictions of nearshore hydrodynamics and bathymetric evolution using an advanced process-based model (Delft3D). Observations of dense remotely sensed and psarse in situ data will be assimilated to continuously improve model performance, and where the data are uncertain or absent, the model will be used to fill in the gaps and construct a more complete estimate of current or near-future conditions.

OBJECTIVES

The objectives of the proposed study are to:

- Develop methods for estimating relevant Delft3D model inputs and outputs from airborne and shore-based video and radar observations

- Develop and implement techniques to assimilate these data in Delft3D

- Validate the assimilation model by hindcasting with the remote observations and sparse in situ data sampled from field experiments

- Improve numerical model formulations to narrow error bands on model predictions

- Generate nowcasts and forecasts of the nearshore environment

APPROACH

The approach is to develop an integrated nearshore modeling system that can be tested for a few sites where multiple information sources are available. Here we focus and the site at Palm Beach, Australia, which has a very short morphodynamic response time scale showing frequenct transitions of near alongshore uniform morphology to complex rip-channeld morphology within a period of O(10) days. The analisys is based on daily time exposures of the waves breaking over the underlying bathymetry. This is in contrast with the sites at Duck (NC) and Egmond (NL) (presented by Roelvink et al., 2007) where multiple obsevations of wave breaking and celerity maps were used to infer the underlying bathymetry.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2007**	2. REPORT TYPE	3. DATES COVERED **00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE **Beach Wizard: Development of an Operational Nowcast, Short-Term Forecast System for Nearshore Hydrodynamics and Bathymetric Evolution**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Delft University of Technology,Civil Engineering and Geosciences,Delft, The Netherlands,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

The central software in the system is the Delft3D model, which is available at NRL and for other ONR-sponsored institutions. This model is uniquely capale of modeling 2D and 3D hydrodynamics and morphodynamic changes over time scales ranging from wave groups to several weeks, at spatial scales resolving rip-current cells and breaker bars (Reniers et al., 2004). In particular, model application at Palm Beach, NSW has contributed significantly to our understanding of nearshore morphodynamic processes (Reniers et al., 2001) showing the strong correlation between spatial distribution of computed wave energy dissipation and observed video intensity on an alongshore variable nearshore bathymetry.

The starting point of this work is the estimation of improved nearshore bathymetry via an iterative data assimilation scheme. Assimilation of (forward) model runs with observations is achieved by adding assimilation-based morphological updates to the physics-based morphological processes already in place. The assimilation is performed on the basis of the mismatch between remotely sensed (from video) and modeled proxies for wave energy dissiaption.

WORK COMPLETED

The work presented here is part of a larger effort in collaboration which has been reported by Roelvink et al. [2007]. That effort was completed earlier this year, whereas we requested an extension without funds to continue our research efforts. This has led to a thorough verification of the Beach Wizard tool on the complex rip-channeled beach at Palm Beach (AUS). In addition, the Beach Wizard concept has been applied to infer the bathymetric evolution after a reset event, where the beach changes from a nearly alongshore uniform bathymetry into a rip-channeled beach topography. Subsequent model calculations mimic this evolution and show the generation of multiple rip channels with alongshore spacing comparable to the observations. However, the locations of the rip-channels are different from the observations.

RESULTS

To calculate the wave breaking at Palm Beach the offshore wave conditions, measured approximately 80 km offshore of Sidney, have to be transformed to the nearshore. To that end a SWAN (Booij et al., 1999, Ris et al., 1999) model computation are performed where a coarse gird is used to translate the offshore conditions measured at the wave buoy to the location of Palm Beach. Next the nested grid is used to calculate the wave conditions within the bay. The output of the nested swan model computation is used to create the boundary conditions for the Delft3D wave/roller/flow calculations. To mitigate effects associated with the half hourly variability of the incident wave field the daily mean wave height, wave direction and wave period are used in the calculations. The resulting computations of the wave energy dissipation are then compared to the day-timex, i.e. the daily averaged intensity image. This approach allows a quick assessment of the underlying bathymetry, i.e. calculations do not have to consider the individual time exposure images and corresponding wave conditions, the day-timex exposures are smooth and robust due to the large number of waves breaking and the tidal cycle can be ignored in the computations. A potential drawback is that steep bed slopes maybe underestimated due to tidal smearing of the position of wave breaking.

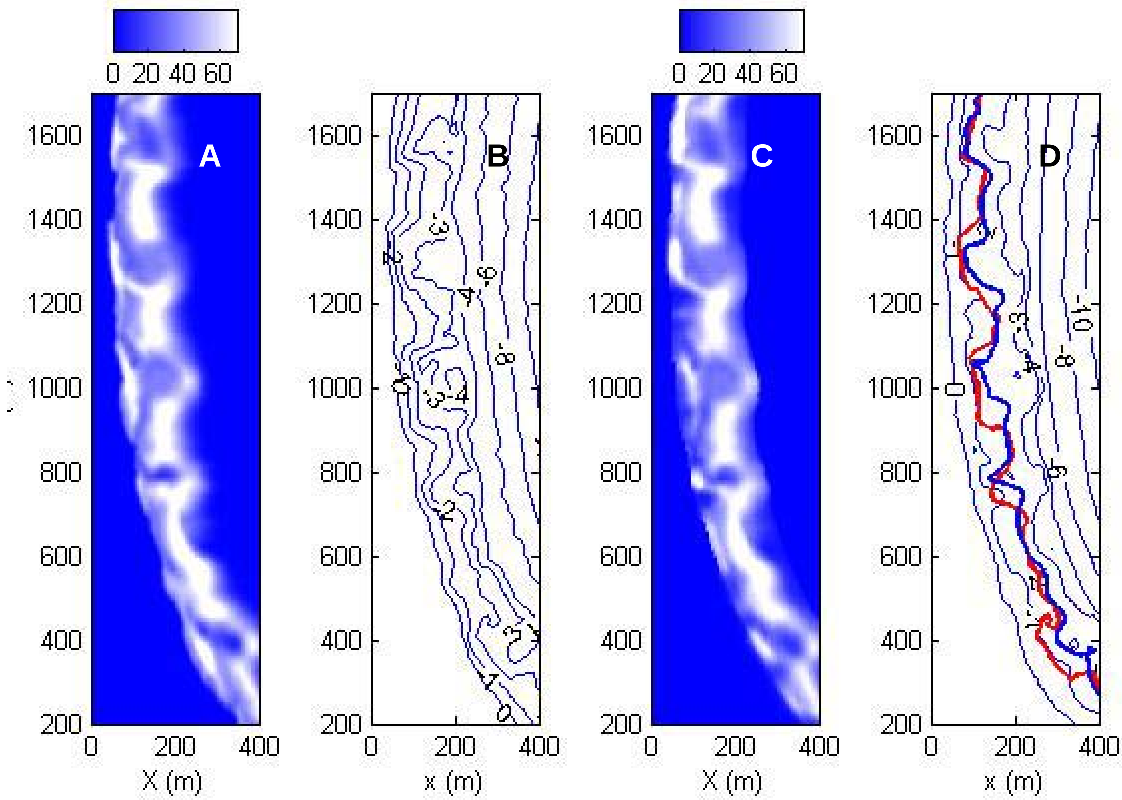

Figure 1. Left panels: Wave dissipation in W/m2 inferred from day-timex on Oct 9, 1999 (panel A) and corresponding bathymetric survey in m water depth with respect to MSL from Oct 14, 1999 (panel B). Right panels: Similar but for the computed wave energy dissipation (panel C) and the beach-wizard inferred bathymetry on Oct 9, 1999 (panel D). The 2 m depth contour from the survey (beach wizard) is indicated in red (blue) (panel D).

The Beach-Wizard inferred bathymetry based on the mismatch criterion between observed and calculate wave dissipation compares well with the survey taking into account that the day-timex was obtained 6 days prior to the survey period (at later times the waves were too small to get a good estimate). The presence of the deeper rip channels and shallow shoals are well predicted, although the details in position and particularly water depth of the channels may differ. The latter is a result of the fact that the absence of wave breaking is not an indicator of the actual depth but off the minimal depth at which waves no longer break (Aarninkhof et al., 2005). Most wave breaking occurs around the 2 m depth contour on Oct 9 for which a good correspondence with the survey is obtained (far right panel in Figure 1).

The Beach-Wizard tool can infer the transition from an alongshore uniform bathymetry to a complex rip channeled beach (upper panels in Figure 2). During the peak of the storm on May 5 1996 the bathymetry shows a terrace like cross-shore profile. In subsequent days this transforms into a single barred system with a clear trough between the shore line and the bar. As the wave conditions become more moderate rip-channels re-appear in the nearshore bathymetry.

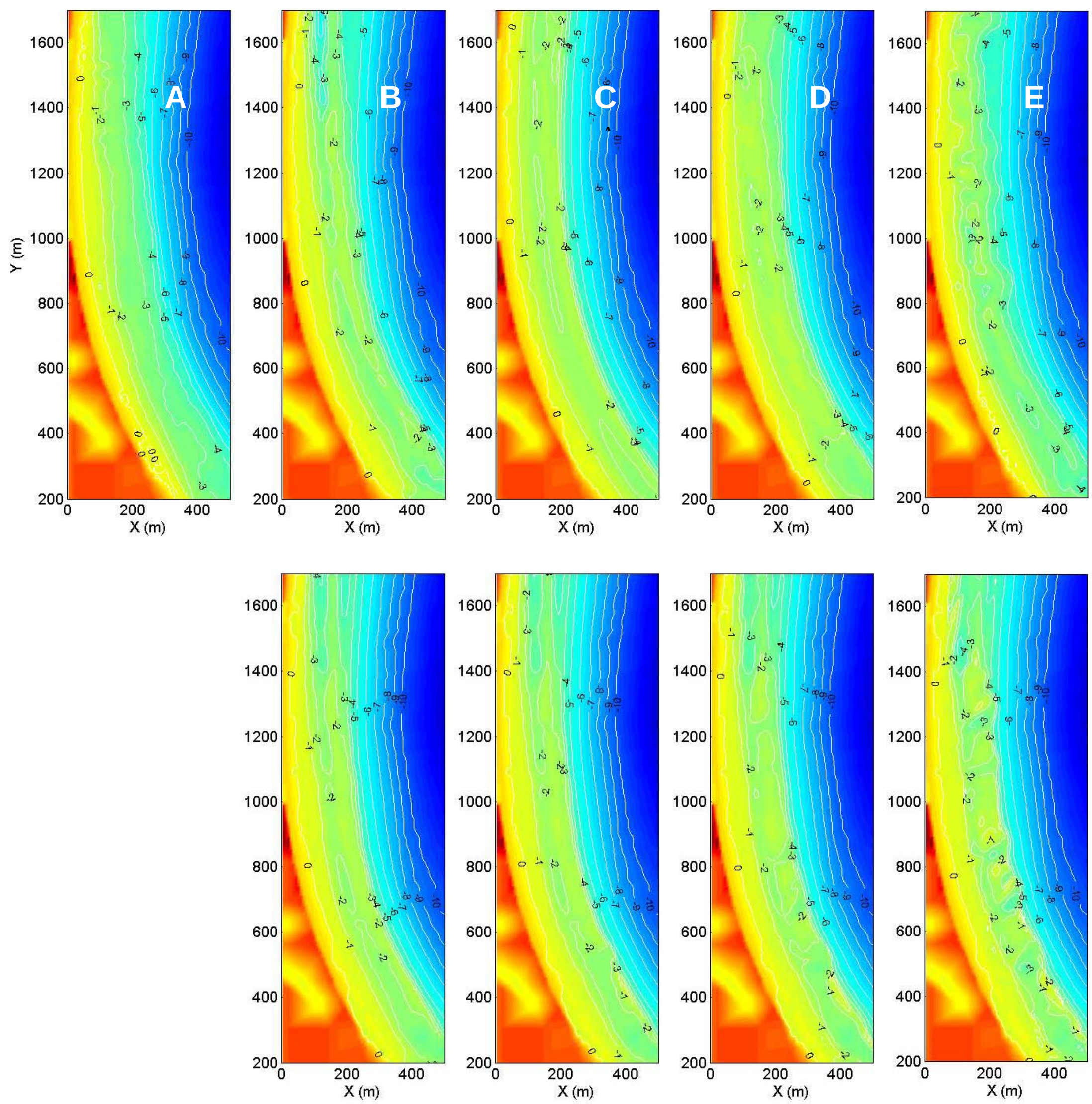

Figure 2. Upper panels: Beach Wizard inferred bathymetries on may 5, 8, 10, 14 and 17, 1996 (panels A through E) showing the transition from alongshore uniform to a rip-channel configuration. Lower panels: Computed morphological evolution starting on May 8 through May 10, 14 and 17. Depth contours in m with respect to MSL.

Using the Beach wizard inferred bathymetry on May 8, 1996 as a starting point for the morphological computations the morphological evolution can be computed (Lower panels of Figure 2). Computations are performed with the settings described in Reniers et al. [2004], i.e. including wave groups, mass flux and wave asymmetry induced sediment transport. The computed morphological evolution shows similar results in the rip channel spacing; however the position of the channels is clearly different.

IMPACT/APPLICATIONS

The Beach Wizard tools allow for the rapid assessment of the nearshore bathymetry and concurrent wave and flow conditions. In addition it is a valuable tool that can be used in evaluating morphodynamic computations by comparing inferred and predicted bathymetries leading to improved model formulations and a better understanding of the dominant physical processes responsible for shaping the nearshore. It can be applied to estimate operational conditions within the surf zone for the navy seals, for the prediction of dangerous rip current flows for swimmers and for coastal monitoring and management.

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